Remarks

Claims 1-73 and 101-129 are pending. Claims 1, 4-5, 23, 35, 101, 106, and 109-110 have been amended.

Claims 35 has been amended to recite "the" heat treatment.

Claims 1, 101, 107, 109 and 110 have been amended to clarify the nature of the "component" as capable of diffusing into and corroding an adjacent metal layer, as described in the specification at page 8 at lines 2-5; page 2 at lines 6-8, and page 3 at lines 16-18.

The amendments are intended to merely clarify language used in the claims, and the scope of the claims is intended to be the same as it was before the amendment in accordance with the invention. No new matter has been added with the amendments.

Rejections under 35 U.S.C. § 112(2)

The Examiner rejected Claims 1-3, 6-10, 35, 101, 106 and 112 under Section 112(2) for the use of indefinite claim language.

Claim 35 has been amended to recite "the" preceding the phrase "heat treatment" as suggested by the Examiner.

The Examiner maintains that the use of "undesirable" in Claims 1-3, 6-10, 101, 106 and 109-112 is unclear. The claims have been amended to recite that the component is capable of diffusing into and corroding an adjacent metal layer, as described in the specification at page 8 at lines 2-5; page 2 at lines 6-8, and page 3 at lines 16-18.

Applicant submits that the claims are clear in their meaning, and satisfy the requirements of Section 112. Accordingly, withdrawal of this rejection is respectfully requested.

Rejections under 35 U.S.C. § 103(a)

The Examiner rejected Claims 1, 2, 3-9, 11-14, 16-19, 21-24, 26-28, 30, 31, 34, 35, 37, 38, 40-45, 49, 68, 71, 101-105, 112, 114, 116, 120 and 121 under Section 103(a) as being obvious over Wang (US 2002/0155218) in view of Hu (USP 6,436,820).

The Examiner maintains the rejection of Claim 115 based on the combination of Wang and Hu with Leem (USP 6,436,820) or Japan '220 (Japan 5-267220).

The Examiner maintains the rejection of Claims 10, 15, 20, 25, 29, 32, 39, 50-59, 61-63, 66, 67, 69, 70, 72, 73, 106-111, 113, 117-119, 122, and 123 based on the combination of Wang and Hu with Leem or Japan '220.

The Examiner also maintains the rejection of Claims 36, 46, 47, 48, 64 and 65 based on the combination of Wang and Hu with Doan (US 2001/0006240).

The Examiner (apparently) maintains the rejection of Claim 48 based on the combination of Wang and Doan with Hu.

The Examiner also maintains the rejection of Claims 60 and 124-127 based on the combination of Wang and Hu in view of "applicant's admitted prior art (AAPA)."

These rejections are respectfully traversed.

The Examiner maintains the rejection of the claims for the following reasons (pages 3-4; emphasis added):

a) There is motivation to utilize a temperature at or greater than 700°C in Wang's process in view of the disclosed temperature of "about 680°C" in Hu *because the "20°C. temperature difference would not have been expected to render the disclosed [Wang's] process inoperable and would be seen as within the range disclosed by "about 680°C"."* (Office Action at page 3, 3rd paragraph).

b) Wang teaches the embodiments of H_2/N_2 plasma and use of temperatures *above* 650°C. (Office Action at page 3, 4th paragraph).

c) The formation of a titanium boronitride layer is disclosed in Leem and Japan '220. (Office Action at pages 4-5).

d) The formation of a titanium silicide ($TiSi_2$) layer by PECVD or sputtering to form a contact is disclosed in Doan (Office Action at page 5).

e) There is motivation to use Hu's RTA at 680°C. in NH_3 in Wang's process to reduce the chlorine content of the titanium nitride film or to reduce contact resistance (Office Action at page 6).

f) The formation of a source/drain contact and/or interconnect is disclosed in the Background of the present application at pages 1-2 (Office Action at page 6).

Applicant believes that the Final Rejection is in error because:

1) There is no motivation to modify Wang's process by increasing the temperature to 700°C or greater.

2) The Examiner mischaracterizes the disclosure in Wang regarding a high process temperature.

3) The Examiner's statement that an increase in temperature in Wang's process would not render Wang's process inoperable is in error.

4) There is no motivation to combine the teachings of Hu with Wang.

5) Wang teaches away from a high processing temperature.

6) The disclosures of the secondary references do not make up for the deficiencies of the Examiner's rejection based on Wang and Hu.

1) <u>There is no motivation to modify Wang's process by increasing the temperature to 700°C or greater.</u>

The Examiner maintains that there is motivation to utilize a temperature at or greater than 700°C in Wang's process based on the disclosed temperature of "about 680°C" in Hu. The Examiner attempts to establish the required motivation to modify Wang based on Hu with the statement (Office Action at page 3; emphasis added):

> One of ordinary skill in the art would have been led to the recited temperature range in view of the disclosed temperature of "about 680°C" with a reasonable expectation of success *because the small, 20°C, temperature difference would not have been expected to render the disclosed process inoperable* and would be seen as within the range disclosed by "about 680°C".

The Examiner is ignoring the specific disclosure of Wang regarding process temperatures.

Wang describes a method of forming a titanium nitride film at a temperature less than 600°C., and treating the TiN film in a plasma treatment step to reduce the chlorine content.

In describing the plasma treatment step, Wang teaches a low temperature of *400-600°C.* See below in Table 2: Pedestal Temp. (°C.) 580 (400-600):

[0044] Table 2 illustrates the typical process conditions for the H_2 plasma treatment...

TABLE 2

Plasma Treatment Process Parameters

	Plasma Treatment Preferred (range)
H_2 (sccm)	2000 (500–5000)
N_2 (sccm) (optional)	2000 (500–5000)
Pedestal Temp. (° C.)	580 (400–600)
Pressure (torr)	5 (0.5–10)
RF power (W)	600 (600–900)
Ar Purge (sccm)	500 (200–1000)

Wang does *not* teach or suggest the use of a higher temperature of about 700°C. or greater in the treatment step as claimed by Applicant to remove chlorine (or other component) from the contact material.

Wang further emphasizes the use of low processing temperatures — *less than 600°C.* — in forming the TiN film, throughout the disclosure (emphasis added):[1]

> Abstract
> A method of forming thick titanium nitride films with low resistivity. Using a thermal chemical vapor deposition reaction between ammonia (NH_3) and titanium tetrachloride ($TiCl_4$), a titanium nitride film is formed ***at a temperature of less than about 600°C.***, ...
>
> ...
>
> [0012] In one embodiment of the present invention, the TiN layer is formed at a pressure of about 20 torr and *a temperature* ***between about 550°C. and about 600°C.*** at...
>
> ...
>
> [0022] In one embodiment, a TiN layer is deposited at an NH_3:$TiCl_4$ flow ratio ...and a *process temperature* ***of less than about 600°C., or preferably about 580°C.***
>
> ...

[1] See also Table 1 (Process Parameters for TiN Deposition) at [0036]: Pedestal Temp. (°C.) 580 (400-600) 580 (400-600). See also Table 2 (Plasma Treatment Process Parameters Plasma Treatment) at [0044]: Pedestal Temp. (°C.) 580 (400-600).

[0035] The present invention provides another embodiment of forming a thick, low stress TiN layer with good step coverage and low resistivity. In particular, the method includes the following features: 1) ***a relatively low deposition temperature of less than about 600°C.***;...

...

[0039] More preferably, the TiN deposition is performed at ...***and a pedestal temperature is maintained at about 400-600°C., e.g., between 500-600°C., and more preferably about 550-600°C.***

...

[0040] Under these process conditions, a crack-free TiN layer 204, having a film stress of less than about ...***With a depositing temperature below about 600°C.***, step coverage can be improved for contact with high aspect ratios, e.g., over 7:1...

...

[0045] The plasma treatment using a hydrogen-containing plasma, ... For example, at a ***temperature of about 580°C.***, a TiN film has a Cl concentration of about 3% ...Typically, the resistivity of a TiN film treated in a H_2/N_2 plasma ...***at about 580°C.*** is less than...

...

[0048] In another aspect of the invention, the film deposition and plasma treatment steps are performed in different sequence combinations in order to achieve various desirable film properties. For example, the recipe of process (b), shown in Table 1, may be used to deposit this layer 304 ***at a temperature of less than about 600°C.***...

Throughout the disclosure, Wang repeatedly emphasizes the use of a low processing temperature of less than 600°C. with both the TiN deposition step and the plasma treatment step. Clearly, based on the repeated statements by Wang emphasizing the use of processing temperatures less than 600°C., there is no motivation to alter Wang's method to utilize a processing temperature higher than 600°C.

2) The Examiner mischaracterizes the disclosure in Wang regarding a high process temperature.

The only disclosure of a higher temperature ("a pedestal temperature of over 650°C.) in Wang is at paragraph [0033] where Wang addresses problems associated with prior art methods that result in *cracked* films — and can be avoided by *decreasing* the deposition temperature (emphasis added).

[0033] *In a typical TiN deposition process, a pedestal temperature of over 650°C. is often used* at a typical NH_3:$TiCl_4$ ratio of about 5. ...***Cracks begin to develop in these films*** that are about 400 Å thick. ***In general, TiN film stress can be reduced by lowering the deposition temperature*** and/or increasing the NH_3:$TiCl_4$ ratio...

This clearly teaches away from temperatures above 650°C and toward dropping the process temperature to *below* *650°C.* Wang's reference to the prior art use of a temperature over 650°C. and pointing out the disadvantages of using a temperature over 650°C. clearly points away from the use of a high processing temperature in forming a TiN contact. Wang's statements explicitly discourage the use of a temperature of over 650°C.

3) The Examiner's statement that an increase in temperature in Wang's process would not render Wang's process inoperable is in error.

Wang specifically teaches a low process temperature to achieve the stated objectives of improved step coverage, low resistivity, and for process integration purposes. Wang also states that the use of a high temperature can cause problems in fabricating a capacitor due to inter-diffusion.

In the Background section, Wang states the problems with high temperature processing (emphasis added):

> [0009] Although the Cl content in the deposited TiN film can be reduced by increasing the deposition temperature, ***improved step coverage is favored by lowering the deposition temperature***. Furthermore, ***a relatively low deposition temperature is advantageous for process integration purposes***. For example, TiN can be used as a barrier layer for an upper electrode in a capacitor structure with tantalum pentoxide (Ta_2O_5) as the dielectric. However, thermal CVD of TiN--e.g., using a reaction between $TiCl_4$ and NH_3, ***is often performed at a temperature of about 650°C. Such a high temperature may cause undesirable atomic inter-diffusion within the capacitor structure***.

> [0010] Therefore, a need exists in the art for a method of depositing TiN *at a reduced temperature*, to yield thick, crack-free TiN films ***having improved properties including good step coverage and low resistivity***.

The advantage of using a low processing temperature to fabricate a thick TiN film with good step coverage and low resistivity, and to avoid film-stress and inter-diffusion across material layers, is repeatedly stated in the Detailed Description (emphasis added):

> DETAILED DESCRIPTION
>
> [0021] The present invention provides a method of forming a thick titanium nitride ...film with low resistivity and good step coverage. ...**Embodiments of the invention allow relatively thick TiN films with low resistivity** to be formed using a reaction between NH_3 and $TiCl_4$ *at a reduced deposition temperature*.

> [0033] *In a typical TiN deposition process, a pedestal temperature of over 650°C. is often used* at a typical $NH_3:TiCl_4$ ratio of about 5. ...***Cracks** begin to develop in these films* that are about 400 Å thick. ***In general, TiN film stress can be reduced by lowering the deposition temperature*** and/or increasing the $NH_3:TiCl_4$ ratio...

> [0035] The present invention provides another embodiment of forming **a thick, low stress TiN layer with good step coverage and low resistivity**. *In particular, the method includes the following features: 1) a relatively low deposition temperature of less than about 600°C.;* 2) an $NH_3:TiCl_4$ ratio of at least about 5...; and 3) H_2 plasma treatment of the deposited film.

> [0051] The bottom electrode 400 ...A TiN barrier layer 406 is then formed upon the Ta_2O_5 dielectric layer 404, ***preferably at a low processing temperature* so as to avoid undesirable inter-diffusion across the various material layers.** This can be achieved, for example, by the process of the present invention. The TiN barrier layer 406 can be deposited using the recipe shown in Table 1, followed by treating in a plasma generated from H_2....

Where a proposed modification or combination of the prior art would change the principle of operation of the prior art invention being modified, then the teachings of the references are not sufficient to render the claims *prima facie* obvious. *In re Gordon*, 733 F.2d 900, 221 USPQ 1125 (Fed. Cir. 1984); *In re Ratti*, 270 F.2d 810, 123 USPQ 349 (CCPA 1959).

Wang's method of forming a TiN film, which has the desired properties of good step coverage and low resistivity, while eliminating film stress, preventing interlayer diffusion, and achieving process integration — is based on the use of a low processing temperature of less than 600°C. The Examiner's proposed modification of Wang to change the processing temperature to 680°C or higher would change the basic principle of operation of Wang's method.

4) There is no motivation to combine the teachings of Hu with Wang.

The Examiner has rejected the claims based on a modification of Wang's processing temperature (i.e., less than 600°C.) to a higher processing temperature of greater than 680°C. as described by Hu.

Obviousness cannot be established by combining the teachings of the prior art to produce the claimed invention, absent some teaching or suggestion supporting the combination. Here, the teachings of Wang and Hu are inconsistent with each other and contain no such suggestion or incentive in support of the modification.

The Examiner maintains there is support for the modification on the basis that the increased temperature would not be expected to render Wang's process inoperable.

Hu teaches forming a TiN plug by annealing a TiN film at 680°C in NH_3 gas. See at cols. 4-5, bridging paragraph; at col. 5 at lines 33-45; at cols. 6, lines 60-65:

> Applicants determined that when a TiN film approximately 200Å thick is annealed in the presence of NH_3,... FIG. 2 shows graph 200, which illustrates the effect on film resistivity of annealing a 200Å thick TiN film, when the film is annealed at **approximately 680°C.**, in the presence of NH_3, at a pressure of about 10 Torr...
>
> ...
>
> Films of various thicknesses deposited using the method of the present invention are represented on Bar Graph 300 by bars labeled 350. These films were CVD deposited in a series of deposition/anneal steps, where each step included CVD deposition of a layer of TiN, followed by annealing in the presence of NH_3. ...After each CVD deposition of an individual film layer, the TiN film (which increased in thickness after deposition of each layer) was annealed in the presence of NH_3 at **about 680°C.,** at a pressure of 10 Torr for about 20 seconds...
>
> ...
>
> 2. Treatment for Residual Chlorine Removal
>
> After the deposition step was competed, and the flow of $TiCl_4$ into the chamber was stopped, the residual chlorine removal treatment was carried out as follows: The substrate, including the TiN film, was maintained at a temperature of **about 680°C.,** ...

While Hu teaches a *high* processing temperature of about 680°C. — as discussed above, Wang teaches the use of a ***low*** processing temperature — specifically teaching a processing temperature of *less than 600°C.* The Examiner is again directed to Wang's statements at paragraphs [0009] and [0035] (above) of the problems with using a temperature of about 650°C. or greater to fabricate TiN films.

Clearly, based on Wang's disclosure, there is no incentive to increase the process temperature of Wang's process to an increased temperature of 680°C. as described by Hu, and certainly not to a temperature of about 700°C. or greater as claimed by Applicant.

In essence, the Examiner is ignoring the explicit teaching of Wang of a low processing temperature. The Examiner has not combined the cited references based on any teaching or suggestion in any of the references, but rather upon his own analysis.

5) Wang teaches away from a high processing temperature.

In addition, Wang essentially teaches away from the present invention, i.e., thermally annealing a contact in a nitrogen-containing gas at a temperature of about 700°C. or greater to remove chlorine from the contact.

A reference teaches away when "a person of ordinary skill, upon reading the reference … would be led in a direction divergent from the path that was taken by the applicant." *In re Gurley*, 313 USPQ2d 1130, 1131 (Fed. Cir. 1994).

Wang specifically teaches in the context of the existing art of forming TiN films, and addresses the problems of cracked films and film stress, step coverage and resistivity, process integration, and inter-diffusion that occur during formation. Wang's solution is to utilize a low processing temperature of less than 600°C. to achieve thick, crack-free TiN films having good step coverage and low resistivity, and good process integration.

Throughout the disclosure, Wang emphasizes the problems and failures with prior art TiN film fabrication processes that utilize higher temperatures. The Examiner is again directed to paragraphs [0009]-[0010] and [0033] (emphasis added):

> [0009] Although the Cl content in the deposited TiN film can be reduced by increasing the deposition temperature, ***improved step coverage is favored by lowering the deposition temperature***. Furthermore, ***a relatively low deposition temperature is advantageous for process integration purposes***. For example, TiN can be used as a barrier layer for an upper electrode in a capacitor structure with tantalum pentoxide (Ta_2O_5) as the dielectric. However, thermal CVD of TiN--e.g., using a reaction between $TiCl_4$ and NH_3, *is often performed at a temperature of about 650°C*. ***Such a high temperature may cause undesirable atomic inter-diffusion within the capacitor structure***.
>
> [0010] Therefore, a need exists in the art for a method of depositing TiN ***at a reduced temperature, to yield thick, crack-free TiN films having improved properties including good step coverage and low resistivity.***
>
> …
>
> [0033] *In a typical TiN deposition process, a pedestal temperature of over 650°C. is often used* at a typical NH_3:$TiCl_4$ ratio of about 5. …***Cracks** begin to develop in these films* that are about 400 Å thick. ***In general, TiN film stress can be reduced by lowering the deposition temperature*** and/or increasing the NH_3:$TiCl_4$ ratio…

Based on the teaching of Wang, one of skill in the art would have no motivation or basis to utilize a high process temperature of about 700°C or greater to remove a residual material as claimed by Applicant.

In sum, Wang, either alone or combined with Hu, does not teach or suggest Applicant's method involving the step of heating a contact in a reactive gas at a temperature of about 700°C. or greater to remove an adverse component (e.g., chlorine) from the contact. Accordingly, withdrawal of the rejections of the claims is respectfully requested.

6) The disclosures of the secondary references do not make up for the deficiencies of the Examiner's rejection based on Wang and Hu.

The Examiner has failed to establish a *prima facie* case of obviousness based on the primary references of Wang and Hu, due to a clear lack of motivation to combine those references. As for the further disclosures of the secondary references — Leem (USP 6,436,820), Japan 5-267220 (Japan '220), and/or Doan (US 2001/0006240) — those references do not make up for the deficiencies of the Examiner's rejection.

The Examiner rejected Claim 115 based on the combination of Wang and Hu with Leem or Japan '220. The Examiner rejected Claims 10, 15, 20, 25, 29, 32, 39, 50-59, 61-63, 66, 67, 69, 70, 72, 73, 106-111, 113, 117-119, 122, and 123 based on the combination of Wang and Hu with Leem or Japan '220.

The Examiner cited Leem and Japan'220 for teaching formation of a titanium boronitride layer to form the contact. The mere formation of a titanium boronitride layer in the titanium nitride films of Wang does not make does not make up for the above-stated deficiencies in the rejection of the claims based on the Examiner's combination of Wang with Hu.

The Examiner rejected Claims 36, 46, 47, 48, 64 and 65 based on the combination of Wang and Hu with Doan.

The Examiner cites Doan for teaching the formation of a titanium silicide ($TiSi_2$) layer by PECVD or sputtering to form a contact.

First of all, Applicant again respectfully points out that Claims 46 and 47[2] do *not* specify the formation of a $TiSi_2$ layer by PECVD or sputtering. Claim 48[3] further defines the *thermal anneal* recited in Claim 46. As to Claims 46-48, the Examiner is requested to *withdraw* the rejection based on Wang and Hu with Doan.

As to Claims 36 and 64-65, the mere formation of a $TiSi_2$ layer in the titanium nitride films of Wang does not make does not make up for the above-stated deficiencies in the rejection of the claims based on the Examiner's combination of Wang with Hu.

The rejection of the claims at page 6 of the Office Action is not clearly stated. Based on the previous Office Action, it is assumed to be directed to Claim 48, which recites that the chlorine content of the contact is less than about 3% by wt. The Examiner's rejection is based on a combination of Wang and Doan with Hu, and his position that there is motivation to use Hu's RTA at 680°C. in NH_3 in Wang's process to reduce the chlorine content of the titanium nitride film below 3% by weight.

Claim 48 does not recite reducing the chlorine concentration to less than 3% by weight. Accordingly, withdrawal of this rejection of Claim 48 is correct and respectively requested.

However, it is noted that Claims 44, 49, 51 and 66-73 recite a chlorine content of less than about 3% by wt. With respect to those claims, the above-stated reasons with respect to the combination of Wang with Hu, it is submitted that there is no motivation to modify Wang's process to utilize a process temperature of 680°C. to reduce the chlorine content of a TiN film. Furthermore, the disclosure in Doan does not make up for the previously stated deficiencies of the Examiner's proposed combination of Wang with Hu.

---

[2] Claim 46 recites: A method of forming a contact, comprising: depositing a first source gas comprising TiCl4, H2, and SiH4 precursors onto a substrate to form a titanium silicide layer in an opening; ... exposing the contact to a nitrogen-containing gas by thermal anneal at a temperature of about 700°C. or greater to reduce the concentration of chlorine of the contact.

Claim 47 recites: The method of Claim 46, wherein the nitrogen containing gas comprises ammonia.

[3] Claim 48 recites: The method of Claim 46, wherein the thermal anneal is conducted at a temperature of at least about 700°C. to about 800°C.

The Examiner rejected Claims 60 and 124-127 based on the combination of Wang and Hu in view of "*applicant's admitted prior art (AAPA)*" regarding the formation of a source/drain contact and/or interconnect (Background at pages 1-2).

First of all, Applicant respectfully points out that Claims 124 and 127 do *not* specify the formation of a source/drain contact or interconnect. As to those claims, the Examiner's rejection is incorrect and *withdrawal* of this rejection of Claims 124 and 127 is respectfully requested.

As to Claims 60 and 125-126, the mere formation of the contact to an S/D region in the substrate, or the formation of an interconnect over the titanium nitride film of Wang does not make does not make up for the above-stated deficiencies in the rejection of the claims based on the Examiner's combination of Wang with Hu.

In sum, there is no motivation to combine the teachings of Wang and Hu, and the teaching of any of the secondary references does not make up for the lack of motivation to combine the primary references, or the above-stated deficiencies of the Examiner's rejections of the claims based on Wang and Hu.

Accordingly, the Examiner has not established a *prima facie* case of obviousness of the claims at issue, and withdrawal of the rejections of the claims is respectfully requested.

Extension of Term. The proceedings herein are for a patent application and the provisions of 37 CFR § 1.136 apply. Applicant believes that no extension of term is required. However, this conditional petition is being made to provide for the possibility that Applicant has inadvertently overlooked the need for a petition for extension of time. If any extension and/or fee are required, please charge Account No. 23-2053.

It is submitted that the present claims are in condition for allowance, and notification to that effect is respectfully requested.

Respectfully submitted,

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Dated: April 7, 2004

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